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Green TFP Intensity Impact on Sustainable East Asian Productivity Growth

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Abstract: This study aims at assessing the effect of carbon dioxide (CO2) per unit of worker (intensity) emissions growth on productivity growth on selected 5 countries of Association of Southeast Asian Nations, (ASEAN5), Malaysia, Indonesia, Philippines, Singapore and Thailand, plus 3 East Asian Countries (China, Japan and South Korea). The results show that there was difference in the contribution of labour productivity, capital deepening and CO2 intensity emissions whether CO2 intensity emissions was included or not in the model. There were, however differences in the growth rates of total factor productivity (TFP) intensity growth. Moreover, a significant decline in the growth rates of TFP intensity growth was observed during the entire period of the study and sub periods, when CO2 intensity emissions variable was internalised in the model. The CO2 intensity emissions had impacted the productivity growth through the declining contribution of green TFP intensity growth in comparison with conventionally calculated

I. INTRODUCTION

Changes in productivity are a major concern in any economy, because of the link between productivity and living standards. The ultimate goals of productivity improvement are greater competitiveness, higher profitability, higher living standards, and better economic and social prosperity. Generally, growth in productivity is associated with a growth in real wages and, ultimately, an improvement in living standards. This paper reviewed most of the past studies related to productivity growth analysis. Combined previous studies related to productivity analysis in general and those related to productivity and environmental impact analysis which is called green productivity in particular. The concept of Green Productivity (GP) is drawn from the integration of two important developmental strategies viz. productivity improvement and environmental protection. Productivity provides the framework for continuous improvement while environmental protection provides the foundation for sustainable development. Therefore, Green Productivity is a strategy for enhancing productivity and environmental performance for overall socio-economic development.

GP was launched in 1994 in line with the 1992 Earth Summit recommendations that both economic development and environmental protection would be key strategies for sustainable development. With the support from the government of Japan, the Asian Productivity Organisation (APO, 2002) introduced GP as a practical way to answer the challenge of sustainable development. The objective of the APO's GP programme is to enhance productivity and simultaneously reduce the negative impacts on the environment. It seeks to realise this objective by propagating GP consciousness. The APO pledges to continue the progress in the Asia-Pacific Region and through cooperation, extend GP to accelerate a growing green global marketplace. Markandya (1998) demonstrated the situation of air and water pollutant emissions as the fast growing region in the world**;** Asia has witnessed a remarkable increase in the level of economic activity over the last quarter century. Inevitably this has been accompanied by increases in emissions of pollutants, with the industrial, energy, and transportation sectors being responsible for both the largest increases in output as well as environmental pollution. In the early years of development, policymakers paid little attention to the environment. Economic growth was the priority and imposing any restraints on the growth was seen as erroneous. Of course some controls on emissions were introduced, but the level of effort that went into environmental regulation remained very low. The same applied to investments in infrastructure, in clean technology, and in the collection and treatment of industrial wastes. The public sector simply did not treat this as a priority category and the incentives on the private sector to undertake such investments remained weak or non-existent.

II. GREEN TFP IMPLICTIONS ON SUTAINABLE ECONOMIC GROWTH

The use of total factor productivity (TFP) overcomes the problems of single productivity indicators such as labour productivity and capital deepening by measuring the relationship between output and its total inputs (a weighted sum of all inputs), thereby giving the residual output changes not accounted by total factor input changes. Being a residual, changes in TFP are not influenced by changes in the various factors which affect technological progress such as the quality of factors of production, flexibility of resource use, capacity utilisation, quality of management, economies of scale and the like (Rao and Preston 1984).

The sustainability of higher economic growth is likely to continue to be productivity driven through the enhancement of TFP. Such enhancement needs to put an emphasis on the quality of workforce, demand intensity, economic restructuring, capital structure, technical progress and environmental standards. It has been documented in empirical work on economic growth by Solow (1956, 1957), that after accounting for physical and human capital accumulation, 'something else' accounts for the bulk of output growth in most countries. Both physical and human capital accumulations are certainly critical for economic growth. The process becomes more complicated with the role of knowledge in the economic growth process. It should be recalled; the green productivity through green TFP demonstrates the concept of sustainable development by progressing technologically and ensures the right of the future of forthcoming generations to enjoy better life.

In this regards, economists are interested in intensive growth, which is expressed in the form of growth in output per worker (labour productivity). Moreover, an economy's standard of living is not determined by its total output but by the amount of output available per person as stated by many economists like Dollar and Sokoloff (1990). This study also uses an intensive growth model instead of using an extensive growth model which was used in previous studies, in order to decompose labour productivity growth into contributions of capital deepening and CO2 intensity emissions as undesirable output or private input. In addition to the simultaneous contribution of the quality of these factors expressed as the TFP per unit of worker (intensity) growth.

Furthermore, the most obvious deficiency in the growth accounting models used in previous studies was found to be the exclusion of externalities such as pollutant emissions generated by the economic growth of these countries. This study aims at contributing to the available literature on the growth accounting method, in that it will draw methods to calculate the TFP intensity growth as residual by internalising the CO2 intensity (CO2 per worker) emissions in addition to the input terms in the conventional production function as un-priced output. Accordingly, TFP intensity growth became an indicator of green productivity, which takes into account economic development and environmental protection such as those in Pittman (1983), Gollop and Roberts (1983), Chaston *et al.*, 1997, Gollop and Swinand (1998), Gollop and Swinand (2001), Harchaoui *et al.* (2002) and Elsadig (2006, 2007 and 2008). For the purpose, the model suggested by Jorgenson *et al.*, (1987) was modified and used in this study. In this regard, justifying why pollution emissions are input would be useful. It is done in Baumol and Oates (1988).

It should be mentioned here that they are few studies empirically measured the issue of green productivity. In this respect, the recent studies are under taking by Elsadig (2006, 2007 and 2008), those applied green productivity applications to Malaysia's manufacturing sector. The current study is attempting to develop applications of green productivity at the aggregate level of selected East Asian countries. The rest of the paper is organized as follows. Section II provides the methodology; Section III discusses the data used for this study. Section IV offers the empirical results, and Section V delivers the conclusions and policy recommendations.

III. METHOD AND ESTIMATION PROCEDURES

In this study, an attempt is made to apply the conventional growth accounting framework developed. These include results achieved by Solow (1956, 1957), which finally brought to fruition by Kendrick (1961) and further refined by Denison (1962), Denison and Edward (1979), Griliches and Jorgenson (1962), Jorgenson *et al.*, (1987), Dollar and Sokoloff, (1990) and Elsadig (2006, 2008).

The main objective of this paper has been to apply the above-mentioned conventional growth accounting framework under assumptions of competitive equilibrium (where factors of production are paid the value of their respective marginal products) and constant return to scale. The Divisia Index basically decomposes the output growth into the contribution of changes in inputs (such as capital, labour, and materials input growth), and TFP growth. In other words, considering the data at any two discrete points of time, say T and T-1 the growth rate of output (GDP) for an economy can be expressed as a weighted average of the growth rates of physical capital (K), labour (L), and pollutant emissions (E) plus a residual term typically referred to as the rate of growth of total factor productivity (TFP). Hence the TFP growth of each economy is computed as the difference between the rate of growth of output and weighted average of the growth in the capital, labour, pollutant emissions.

According to Mahadevan (2001), the TFP growth studies on the Malaysian manufacturing sector have used the nonparametric translog-divisia index approach developed by Jorgenson *et al*. (1987). This approach does not require the explicit specification of a production function, but the major drawback is that it is not based on statistical theory and, hence, statistical methods cannot be applied to evaluate their reliability, thus casting doubts on their results.

In this regard, the production function for economies can be represented as follows:

$$GDPt,i = F(Kt,i, Lt,i, CO2t,i, Tt,i) \tag{1}$$

where for Country $i = 1, 2, \ldots, 8$ in Year t =1965-2006, the output is annual real GDP, and the inputs are: real fixed physical capital K, number of persons employed L, CO_2 emissions and time T, that proxies for total factor productivity (TFP) as a technological progress of the countries.

In this study the Divisia Index basically decomposes the aggregate output growth into the contribution of changes in inputs (such as aggregate capital, labour, CO_2 emissions growth), and TFP growth. This calculates the productivity indicators to show the reliability of the results generated without considering statistical analysis.

This study attempts to fill this gap by developing the model below into a parametric model and providing its statistical analysis in the first step as follows:

$$\ln GDPt,i = \alpha + a.\ \ln Kt,i + \beta.\ln Lt,i + \lambda.\ln CO2t,i + \varepsilon t,i \qquad t = 1965\text{-}2006 \tag{2}$$

where

α is the output elasticity with respect to capital

β is the output elasticity with respect to labour

λ is the output elasticity with respect to CO_2

a is the intercept or constant of the model[1]

ε is the residual term[2]

ln is the logarithm to transform the variables.

Moreover, following Dollar and Sokoloff, (1990), Wong (1993), Felipe (2000) and Elsadig (2006, 2007, and 2008); when constant returns $\beta = (1 - \alpha - \lambda)$ to scale is imposed, equation (2) becomes:

$$\ln GDPt,i = a + \alpha.\ln Kt,i + \lambda.\ln CO2t,i + (1 - \alpha - \lambda).\ \ln Lt,i + \varepsilon t,i \qquad t = 1965\text{-}2006 \tag{3}$$

For the purposes of this study, equation (3) is transformed by dividing each term by L (labour input) and then the output elasticity is calculated with respect to capital deepening and CO_2 intensity emissions, i.e. $\bar{\alpha}$ and $\bar{\lambda}$, respectively it becomes:

1 The intercept term, as usual, gives the mean or average effect on dependent variable of all the variables excluded from the model.

2 The residual term proxies for the total factor productivity growth that accounts for the technological progress of the economy through the quality of input terms.

$$\Delta \ln(GDP/L)t,i \quad = b + \bar{\alpha}.\Delta \ln \overline{(K/L)}t,i + \bar{\lambda}.\Delta \ln \overline{(CO2/L)}t,i + \Delta \ln(TFP/L)t,i \tag{4}$$

Then, it follows that

Δln(GDP/L)t,i is the conribution of labour productivity (output per worker)
$\bar{\alpha}\Delta$ln(K/L)t,i is the contribution of the Capital deepening
$\bar{\lambda}\Delta$ln(CO2/L)t,i is the contribution of the CO2 intensity emissions
Δln(TFP/L)t,i is the residual term that proxies for TFP intensity growth
Δ is the difference operator denoting proportionate change rate.

To calculate the average annual contribution growth rate of the TFP intensity and labour productivity as well as the contribution of the capital deepening and CO2 intensity, in view of the fact that the intercept (b) has no position in the calculation of the productivity growth rate indicators equation (4) becomes:

$$\Delta \ln(TFP/L)\, t,i = \Delta \ln(GDP/L)\, t,i - [\bar{\alpha}\ .\Delta \ln \overline{(K/L)}\, t,i + \bar{\lambda}\ .\Delta \ln \overline{(CO2/L)}\, t,i\,] \tag{5}$$

Thus, equation (5) expresses the decomposition of labour productivity growth into the contributions of capital deepening, increasing usage of CO2 intensity, and the simultaneous contribution of the quality of these factors. This is expressed as the TFP intensity growth.

IV. DATA SOURCES

The data for this paper were collected from various sources. Real Gross Domestic Product (GDP) in US dollars millions, real fixed physical capital in US dollars millions, number of employment, was collected from Asian Development Bank: Key indicators of developing Asia and Pacific countries, Statistical and Data Systems Division, and international financial statistics of International Monetary Fund and World Development Indicators online database system. Due to lack of data on man-hours of work, the labour input index is constructed based on the number of persons employed. Data of CO2 emissions (CO2 (in kilo tonne (Kt)) were found to match with the time series data of the other variables of the study for the period of 1965-2006 at World Development Indicators online database.

V. ECONOMTERIC ANALYSIS

Autoregressive estimator has been applied to equation 4 of the model being generated from Cobb-Douglas production function to measure the shift in the production functions of ASEAN-5 plus 3. An annual time series data over the period of 1965-2006 for GDP, aggregate fixed physical capital, number of employment and CO2 emissions (CO2 (in kilo tonne (Kt)) have been employed for the individual countries.

In view of the fact that the model used in this study was specified in first differences and the calculated growth rates were used in the discussion of results and findings of the study, the model was found to be stationary. In addition, (Table1) presents the results of the unit root tests conducted. Likewise, Engle and Granger (2003), state that if economic relationships are specified in first differences instead of levels, the statistical difficulties due to non-stationary variables can be avoided because the differenced variables are usually stationary even if the original variables are not.

Table 1: Results of the Phillips-Perron (PP) Unit Root Test First Difference

Country	GDP	Capital	Labour	CO2
1. China	-6.26* -6.25**	-6.13* -6.15**	-6.32* -6.24**	-3.99* -3.98**
2. Indonesia	-3.34* -3.89**	-4.00* -4.59**	-7.17* -7.07**	-5.94* -5.93**
3. Japan	-1.53* -3.67**	-2.42* -3.72**	-4.75* -6.01**	-3.32* -3.98**
4. Korea	-2.30* -3.90**	-3.65* -4.81**	-6.14* -6.06**	-5.69* -6.87**
5. Malaysia	-5.16* -5.11**	-4.08* -4.13**	-6.34* -6.26**	-6.78* -6.72**
6. Philippines	-4.91* -5.50**	-4.37* -4.82**	-6.26* -6.19**	-5.01* -5.26*
7. Singapore	-3.46* -4.31**	-2.92* -3.78**	-6.07* -6.29**	-6.77* -6.83**
8. Thailand	-3.51* -3.67**	-3.48* -3.55**	-6.27* -6.25**	-5.53* -5.79**

Notes: Figures in *Table 1* are T test-values showing significance at 1%, 5% and 10%
* Constant without trend
** Constant with trend

Table 2: Estimated Coefficients of ASEAN 5 + 3, without CO2, 1965-2006

Country	Intercept	Capital Deepening	Adjusted R^2	D-H
1. China	0.13 (7.26)**	0.90 (9.69)**	0.99	0.41
2. Indonesia	-0.31 (-1.79)*	0.70 (7.58)**	0.98	0.93
3. Japan	0.17 (5.75)**	0.83 (7.49)**	0.99	0.83
4. Korea	0.20 (4.03)**	0.97 (8.25)**	0.98	0.62
5. Malaysia	0.14 (1.68)*	0.85 (7.20)**	0.99	0.67
6. Philippines	0.27 (2.49)**	0.82 (8.56)**	0.99	0.15
7. Singapore	0.81 (7.36)**	0.50 (4.55)**	0.99	0.32
8. Thailand	0.18 (2.36)**	0.95 (10.40)**	0.97	0.24

Notes: Figures in parentheses are t-values
** Significant at 5% level
* Significant at 10% level
Figures in *Table 2* were estimated using equation (4)

Table 3: Estimated Coefficients of ASEAN 5 + 3, with CO2, 1965-2006

Country	Intercept	Capital Deepening	CO2 Intensity	AdjustedR^2	D-H
1. China	0.10 (1.22)	0.88 (7.64)**	0.12 (2.69)**	0.97	0.34
2. Indonesia	-1.00 (-3.71)**	0.89 (7.91)**	0.11 (2.89)**	0.96	0.44
3. Japan	0.16 (1.01)	0.93 (8.21)**	0.07 (1.66)*	0.97	0.34
4. Korea	0.76 (6.04)**	0.90 (8.17)**	0.10 (2.29)**	0.97	0.25
5. Malaysia	0.72 (5.92)**	0.85 (7.86)**	0.15 (3.69)**	0.97	0.14
6. Philippines	0.19 (1.94)*	0.82 (7.07)**	0.18 (2.30)**	0.96	0.30
7. Singapore	0.19 (2.04)**	0.84 (7.12)**	0.16 (3.74)**	0.96	0.32
8. Thailand	0.38 (3.88)**	0.78 (6.06)**	0.22 (2.33)**	0.95	0.36

Notes: Figures in parentheses are t-values
** Significant at 5% level
* Significant at 10% level
Figures in *Table 3* were estimated using equation (4)

Analysis of the data using equation 4 has shown that the estimated coefficients of the explanatory variables of the model mainly were significant at 5% and 10% levels. According to Durbin-H values the model has no problem of autocorrelation. In addition, the adjusted R^2 and t-values did not indicate multicollinearity in the model (*Tables 2* and *3*). It should be recalled that there is no significant difference in the unit roots test results at the first difference of the individual countries as stated in *Table 1*. The results show that all the variables of the individual countries are stationary. The same trend has been observed in the results of estimated coefficients that reported in *Tables 2* and *3*. These estimated coefficients show the homogeneous measures of these variables of the individual countries, as there is no significant difference between these countries estimated coefficients were observed. These estimated coefficients satisfy the econometric requirements and plug in the divisia index modified model to calculate the productivity indicators used in the study and reported in *Tables 4* and *5*.

VI. EMPIRICAL ANALYSIS

Analysis was carried out to compare the productivity indicators between the ASEAN-5 plus 3 economies for the entire period of 1965-2006. In order to study the effect of governments' policies in improving the productivity growth, the study period was divided into two phases. These phases, which corresponded to the major policy changes, were 1965-1987; 1988-2006. The period of the 1960s; and 1970s witnessed the labour driven policies in these countries and the birth of new era of export-oriented economies. The decades of 1980s, 1990s and 2000s saw a further diversification of the economies of these countries into more advanced industries through investment driven policies and trade liberalisation that had attracted foreign direct investment (FDI) which brought to these countries through Transnational Corporations (TNCs), investment. As a result of these polices the range of economic activities and sources of growth had become more diversified. During these decades, the economic structural transformation took place in most economies of these countries. The manufacturing sector became the engine of growth in these countries. Finally, it includes the period of 1988-2006, i.e. was the period of pre and post the Asian financial crisis of 1997.

In measuring the impact of pollutant emissions on the AEAN-5 plus 3 productivity growth, the carbon dioxide intensity emissions was used as a measure of air pollutant emissions. The results show that the contribution of labour productivity, capital deepening and CO2 intensity were no different whether CO2 intensity emissions was included or not in the model (*Tables 4*

Table 4: ASEAN 5 + 3 Productivity Indicators (in percentage), without CO2

	Country	Labour Productivity	Capital Deepening	TFP Intensity
1.	China			
	1965-2006	5.51	4.62	1.33
	1965-1987	4.68	3.72	1.30
	1988-2006	6.52	5.70	1.35
2.	Indonesia			
	1965-2006	5.25	3.35	1.21
	1965-1987	6.14	4.18	1.26
	1988-2006	5.47	5.11	1.28
3.	Japan			
	1965-2006	6.92	6.24	1.73
	1965-1987	6.64	5.99	1.65
	1988-2006	7.26	6.53	1.82
4.	Korea			
	1965-2006	6.33	6.17	1.87
	1965-1987	6.36	6.16	2.25
	1988-2006	7.30	6.18	1.41
5.	Malaysia			
	1965-2006	4.49	4.12	1.14
	1965-1987	6.12	4.49	1.13
	1988-2006	5.37	5.37	1.32
6.	Philippines			
	1965-2006	4.82	4.95	1.74
	1965-1987	5.19	4.09	1.81
	1988-2006	4.75	6.00	1.64
7.	Singapore			
	1965-2006	5.82	4.95	1.80
	1965-1987	5.19	4.98	1.77
	1988-2006	6.23	5.40	1.99
8.	Thailand			
	1965-2006	4.47	4.74	1.75
	1965-1987	5.70	5.31	1.99
	1988-2006	6.28	5.68	1.46

Note: Figures in *Table 4* were calculated using equation (5).

and 5). There were, however differences in the growth rates of TFP intensity growth in all of the study periods. A significant decline in the growth rates of TFP intensity growth was observed during the entire period of the study and sub periods, when CO2 intensity emissions variable was added to the model. The CO2 intensity emissions had impacted the productivity growth through the declining contribution of TFP intensity growth in comparison with traditionally calculated. (*Tables 4* and *5*): The sub-period of 1965-1987 was found to be a combined period of labour and investment driven policies. On the other hand, the sub period of 1988-2006 was the perceived period of investment driven. As a result the performance of the economies of these countries was rapid compared with the period before the transformation of these economies into investment driven that supported by FDI with high amount pollutants emissions being produced as undesirable output besides the desirable output.

Table 5: ASEAN 5 + 3 Productivity Indicators (in percentage), with CO2

	Country	Labour Productivity	Capital Deepening	CO2 Intensity	TFP Intensity
1.	China				
	1965-2006	5.51	4.62	14.2	-1.56
	1965-1987	4.68	3.72	13.7	-.50
	1988-2006	6.52	5.70	14.8	-1.62
2.	Indonesia				
	1965-2006	5.25	3.35	11.4	-0.96
	1965-1987	6.14	4.18	10.8	-0.95
	1988-2006	5.47	5.11	12.2	-0.99
3.	Japan				
	1965-2006	6.92	6.24	13.6	-0.06
	1965-1987	6.64	5.99	13.4	-0.06
	1988-2006	7.26	6.53	13.9	-0.05
4.	Korea				
	1965-2006	6.33	6.17	11.7	-0.36
	1965-1987	6.36	6.16	11.0	-0.29
	1988-2006	7.30	6.18	12.6	-0.45
5.	Malaysia				
	1965-2006	4.49	4.12	10.2	-1.01
	1965-1987	6.12	4.49	9.41	-0.71
	1988-2006	5.37	5.37	11.3	-1.37
6.	Philippines				
	1965-2006	4.82	4.95	10.5	0.18
	1965-1987	5.19	4.09	10.1	0.20
	1988-2006	4.75	6.00	10.8	0.15
7.	Singapore				
	1965-2006	5.82	4.95	10.1	-1.03
	1965-1987	5.19	4.98	9.47	-0.95
	1988-2006	6.23	5.40	10.7	-1.12
8.	Thailand				
	1965-2006	4.47	4.74	10.9	-2.08
	1965-1987	5.70	5.31	9.94	-1.88
	1988-2006	6.28	5.68	11.7	-2.32

Note: Figures in *Table 5* were calculated using equation (5).

VII. CONCLUSION AND POLICY RECOMMENDATIONS

This paper contributes to the available literature of the growth accounting method in the area of calculating the green TFP intensity as a residual by internalising CO2 intensity emissions in addition to the capital deepening in the production functions of ASEAN-5 plus 3 in comparison with conventionally calculated. By this technique TFP intensity growth became an indicator of green productivity, which puts economic development and environmental protection into consideration.

This study also uses an intensive growth model instead of using an extensive growth model which was used in previous studies, in order to decompose labour productivity growth into contributions of capital deepening and CO2 intensity emissions as undesirable output or private input. In addition to the simultaneous contribution of the quality of these factors expressed as the TFP per unit of worker (intensity) growth.

This study closed the gap of growth accounting theory model by providing statistical analysis in a parametric form that removed the doubt in the results generated. Its results confirm that the higher level of air pollutant emissions generated by these countries economic development had slowed the growth rates of TFP intensity in comparison with traditionally calculated. This impact is due to internalising the CO2 intensity emissions generated by these countries economic growth in addition to the traditional input terms in the form of an un-priced public bad or undesirable output produced.

Finally, this paper found that economic activities are related to the growth rate of CO2 intensity emissions generated by the economies of these countries. This appears in the form of an un-priced public bad that had slowed the productivity growth of these economies in general and the contributions of TFP intensity growth of the these economies in particular.

A CO2 emission data was found to match with the time series data of the other variables of the study for the period of 1965-2006. Furthermore, there are no environmental taxes introduced by most of these countries for the abatement of pollutant emissions by the firms involved in the economic activities in them and tradable permits to curb the pollution. In addition, no money values are attached to the environmental regulations to protect the environment in these countries.

It has been found that the inclusion of CO2 emissions in this study was the main causes of East Asian productivity growth slowdown in general, which had been internalising in the models. The main impact of CO2 emissions was on TFP per unit of labour growth, it is observed in the real values of green TFP per unit of labour compared with before adding the CO2 emissions to the model. As has been mentioned earlier, productivity is the key factor of industrial development in general and economic development of the nations in particular. Applying command and control measures and market-based instruments to curb the pollution through the imposition of environmental taxes and applying the environmental regulations will protect the nation's health and the life of the people. Right now there are many health problems especially during the haze periods in countries like Malaysia, Indonesia and Singapore that caused a lot of economic losses due to shutting down the economic activities in general and industrial activities in particular which had affected the life of the nation. Economic losses were also found in the agricultural sector, tourism industry and other sectors of the Malaysian economy.

Applying the green productivity to economic activities that is introduced by Asian Productivity Organization is of an urgent need to protect human health in these countries especially during the haze period that is caused by burning the forests in Indonesia as a cheap method of investment by East Asian and Multinationals Companies. The tradition method of development (pollutes now and clean up later) that is practice by most of the countries around the globe in general and East Asian in particular should be replaced by green productivity implementation to achieve sustainable development.

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